Section A: Overview of the Research Project Proposal

1. Masters
2. Engineering
3. RF dedispersion networks for pulsar timers
4. Pulsar astronomy relies heavily on dedicated data processing systems known as pulsar timers. A key function of these timers is pulsar dedispersion; applying a receiver channel to the received data with a non-uniform time delay profile over frequency, to negate the dispersion of pulsar observation data. This data processing is typically achieved with digital filter banks, but these are expensive to construct and operate due to their high power consumption (among other reasons). Recently, a mathematical method for implementing arbitrary dispersion profiles using second-order delay networks was demonstrated. In addition, it was shown that these second-order networks can be implemented at RF frequencies. This purpose of this project is to combine these techniques, implementing RF domain (as opposed to digitized) dedispersion networks for pulsar timers. It is expected that this would ease the burden on the digital back-end of pulsar instruments significantly.

Section B: Supervisor(s) Details

1. Primary supervisor's details

a. Dr Tinus Stander
b. University of Pretoria
c. tinus.stander@up.ac.za
d. Supervision of postgraduate students
i. Doctoral Students:

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Piotr Osuch (Also supervised for M.Eng)	RSA	01/2016	07/2018	Synthesis and monolithic integration of in-system analogue data pre-processing networks	
Flavien Sagouo Minko	Cameroon	01/2014	12/2018 (part-time)	Broadband, radiation hardened mm-wave components for space-based Sun observation instruments	
Brilliant Habeenzu	Zambia	02/2015	12/2018 (part-time)	Radiation degradation characterization and modelling in mm-Wave microelectronics	
Titus Oyedokun	Nigeria	01/2014	08/2018	Planar Groove Gap Waveguide	Prof. RH Geschke (primary, UCT)
Hannes Venter (Also supervised for M.Eng)	RSA	06/2018	12/2020	Dispersive and multi-band phase shifters	

ii. Masters Students

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Nishant Singh	India	01/2015	05/2017	Active Q-Enhanced Tunable High-Q On-Chip E-band Resonators and Pseudo-Combline Coupled Resonator Filters in 130nm SiGe BiCMOS	
Vishal Bhana	RSA	01/2013	11/2017 (part-time)	A Slow-Wave CMOS Delay Line Filter for mm-Wave Applications	Prof. S. Sinha (UP)
Shaunel Walker	RSA	01/2016	12/2018	Low cost RF PCB integrated front-ends for mm-wave water vapour radiometry	Mr AC de Villiers (TUT)
Edward Hunter	RSA	01/2017	12/2018	Radially distributed mm-wave array antennas	Prof. DIL de Villers (SU)
Anthony Gaskell	RSA	01/2016	12/2018 (part-time)	Resonant tunnelling diode based analogue to digital converters	Prof. WE Meyer (UP)
James Smith	RSA	01/2014	12/2018 (part-time)	A substrate integrated waveguide amplifier matching scheme	

2. Co-supervisor / Research Supervisor's details (if relevant): N/A

Section C: Full Research Project Proposal

1. Scientific merit:

Pulsar astronomy relies heavily on dedicated data processing systems known as pulsar timers. A key function of these timers is pulsar dedispersion; applying a receiver channel to the received data with a non-uniform time delay profile over frequency, to negate the dispersion of pulsar observation data when travelling through space. These dedispersion profiles have several governing parameters, and a general purpose instrument needs to be able to implement different dedispersion profiles.

This data processing is typically achieved with digital filter banks, but these are expensive to construct and operate due to their high power consumption (among other reasons). Digitized raw pulsar data also requires significant storage space, driving the need for real-time processing.

Recently, a mathematical method for implementing arbitrary dispersion profiles using second-order delay networks was demonstrated. It was found that a given profile can be approximated to an arbitrary minimax error, without the need for initial solutions to the optimization problem. In addition, it was shown that these second-order networks can be implemented at RF frequencies. This can be done either using microwave C-sections in RF PCB, or on-chip using either second generation current conveyor (CCII)-based or inductive feedback-based circuits. It was also found that these networks can be made tunable, to enable dynamic adjustment of the dispersive profile.

This purpose of this project is to combine these techniques: the numerical synthesis methods, along with the physical implementation. It will evaluate the requirements of dedispersion profiles in pulsar timers, and synthesise suitable networks. It will, then, implement such a network in RF, and evaluate the pre-processing network's effect on digitization and data storage requirements.

2. Feasibility:

The underlying synthesis theories have been established in a prior SARAO-sponsored PhD study. In the event that the approach is found infeasible for the application, a concept demonstrator will be produced that illustrates the limitations of the approach.

The M4 lab at the University of Pretoria has significant experience in designing and testing mixed signal and RF circuits. The lab is further equipped with all the necessary laboratory facilities for measurement, as well as software for circuit and system modelling.

Potential objectives for this project would be:

Y1: Coursework. Literature review. Identify the required dedispersion profiles for pulsar timers. Complete a theoretical synthesis.

Y2: Synthesis of constituent circuit blocks. Implementation and evaluation. Establish limits of tuning range.

3. This proposal links to Research Priority Area 1: Radio Pulsar and Fast-Transient science, instrumentation and data analysis (including real-time RFI detection). Even if the approach is found infeasible for pulsar dedispersion, it might be an interesting technique for instantaneous frequency measurement (IFM) receivers, which may be used to find transient RFI sources.

4. The preferred candidate would have some undergraduate background in high frequency electronics and / or electromagnetics. This would include knowledge of basic RF components (transmission lines, filters, couplers, mixers, amplifiers) as well as RF simulation software. Knowledge of optimization and machine learning techniques would also be beneficial.

Section D: Signatures

1. Signed: T. Stander ____________________ Date: 31 August 2018